Transportation Asset Management Case Studies

Presented by

U.S. Department of Transportation
Federal Highway Administration

LIFE-CYCLE COST ANALYSIS

The Pennsylvania Experience

Note From the Director

The Federal Highway Administration's Office of Asset Management is promoting aggressively a different way for transportation agencies to distribute their resources among alternative investment options. This new way of doing business, referred to as "Asset Management," is a strategic approach to maximizing the benefits resulting from the expenditure of agency resources.

For any transportation agency, the progression toward Asset Management will involve a myriad of activities. These endeavors will differ from State to State. For example, some agencies will pursue a data integration strategy in order to ensure comparable data for the evaluation of investment alternatives across asset classes. Others will move to deploy economic analysis tools to generate fact-based information for decision makers. Still others will want to integrate new inventory assessment methods into their decision-making processes.

Much can be learned from those who are readying their organizations for Asset Management. To spark the exchange of information, we are initiating a series of case studies focused on agencies that are leading the way. In this, the inaugural year of the series, we established four tracks: data integration, economics in Asset Management, the Highway Economic Requirements System–State Version, and life-cycle cost analysis. In upcoming years we will add new State reports to each of the tracks and will create new tracks addressing additional facets of Asset Management such as change management and performance measurement.

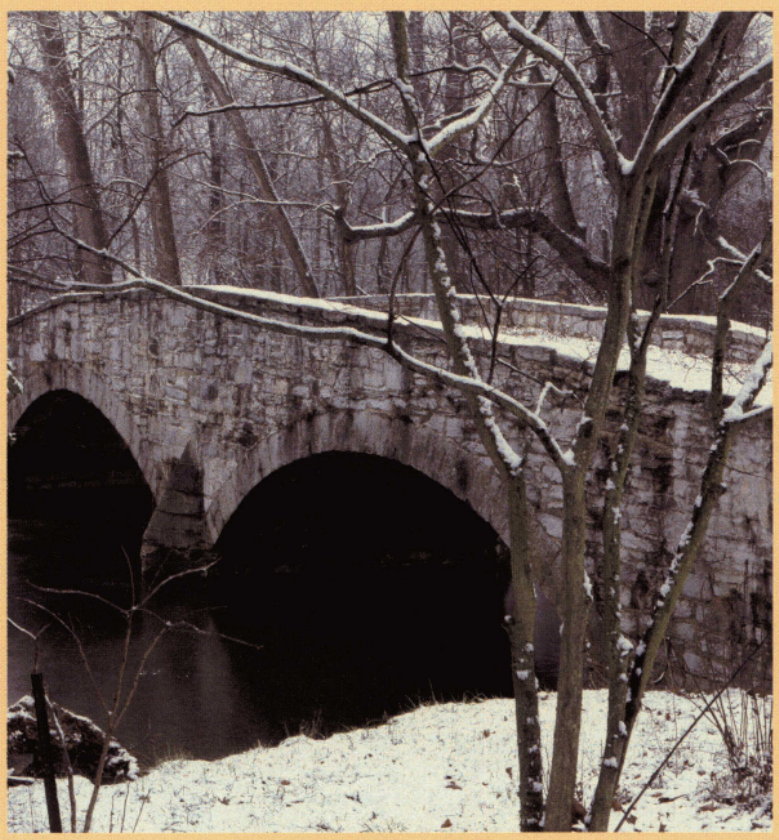
On behalf of the Office of Asset Management, I am pleased to introduce this new series. We believe the case studies will help agencies meet the challenges of implementing Asset Management programs.

David R. Geiger

David R. Geiger
Director, Office of Asset Management

Note to the Reader

The Transportation Asset Management Case Study Series is the result of a partnership between State departments of transportation and the Federal Highway Administration's (FHWA's) Office of Asset Management. FHWA provides the forum from which to share information, and the individual States provide the details of their experiences. For each case study report, State transportation staff were interviewed by FHWA, and the resulting material was approved by the State. As such, the case study reports rely on the agencies' own assessment of their experience. Readers should note that the reported results may or may not be reproducible in other organizations. ■



Welty Stone Bridge, Waynesboro

Executive Summary

Life-cycle cost analysis (LCCA) is an engineering economic analysis tool useful in comparing the relative merit of competing pavement design alternatives. This analytical approach uses a structured methodology to account for the costs of agency activities and the effects of those activities on transportation users. By considering all of the relevant costs incurred during the service life of an asset, the LCCA process helps transportation officials to select the lowest total cost option and provides a means to balance user impacts with the construction, rehabilitation, and preservation requirements of the pavement itself.

> Life-cycle cost analysis can be used to compare the relative merit of competing pavement design alternatives, helping transportation officials identify the lowest total cost approach that meets the performance requirements of a project.

The Pennsylvania Department of Transportation (PennDOT) has a long and successful history of using LCCA in its pavement selection decision process. Since the mid 1980s, PennDOT has conducted an LCCA for all interstate pavement projects with an estimated initial cost of more than $1 million and for all other pavement projects with an estimated cost of more than $10 million. PennDOT has 15 to 20 projects each year that are of sufficient scale to warrant an LCCA. For these projects, PennDOT bases its design selections primarily upon life-cycle costs and includes the effects of user delay and increased vehicle operating costs due to the presence of a work zone. Because of its LCCA policy, PennDOT has achieved significant improvements in its pavement program including—

- Improved overall performance of pavements in the State
- Lower costs for new pavements and rehabilitation work
- Improved credibility of pavement-type selection decisions with the public and industry groups ■

AGENCY FACTS

Although PennDOT's 11 engineering districts are somewhat autonomous, approvals for pavement projects that require life-cycle analysis are the responsibility of the department's central office.

Pennsylvania supports the fifth largest State-owned highway network in the Nation with almost 100,000 lane miles of pavements. The State has large urban centers but also extensive rural and recreational areas. The Pennsylvania Department of Transportation (PennDOT) is headquartered in Harrisburg, the State capital, and has 12,000 employees statewide. Pennsylvania's extensive transportation network involves a variety of facilities and conditions:

- 20,000 lane miles of pavement rehabilitation annually
- Average daily traffic exceeding 100,000 vehicles on many major routes, with 100.4 billion vehicle miles traveled statewide annually
- 16 percent truck traffic, the highest percentage in the Northeast

PennDOT has divided the State into 11 fairly autonomous engineering districts, and each district is responsible for the DOT's infrastructure within its geographical boundaries. However, final approval for pavement projects that require life-cycle cost analysis rests with the PennDOT central office.

SETTING THE STAGE

What Did PennDOT Have?

In the late 1970s, PennDOT saw its list of pavements requiring rehabilitation growing steadily and the State's transportation spending on pavement rehabilitation reaching historically high levels. User delays due to agency work zones were mounting. The department faced increasing internal and external requirements to demonstrate its good stewardship of public funds.

PennDOT recognized the importance of improving maintenance and rehabilitation practices with regard to the serviceability of its pavements and sought to provide the best pavement performance of the road network with the funds available. Pavements were designed according to standards of the American Association of State Highway and Transportation Officials (AASHTO); however, the pavement-type selection component of the design process was much less standardized. Pavement types were often selected on the basis of initial costs and expert opinion. As the list of backlogged pavement needs grew, the choice of paving material—ordinarily within the purview of the design engineer—was becoming a source of contention within and outside of the department.

What Did PennDOT Want?

PennDOT wanted a means to select pavement types that would meet both the initial and long-term performance requirements for a project. The goal was to determine what the total cost implications were for its pavement decisions. The department wanted to ensure that each project could fulfill its life-cycle performance requirements for the lowest cost.

PennDOT recognized the disruptive effects that construction work zones can have on road users. Road construction work zones cause delay and increase vehicle operating costs. PennDOT also understood that its pavement decisions would be scrutinized by the legislative and executive branches of the State government,

Until the mid 1980s, PennDOT selected pavement types on the basis of initial cost and expert opinion. With growing investment requirements, decisions about paving materials were becoming a source of contention.

PennDOT found that pavement decisions are scrutinized within the State government and by the paving industry and the general public. LCCA could provide a means to document and communicate the data and assumptions that were used in a project selection.

the paving industries, and the public at large.

PennDOT identified LCCA as an analytical tool that could meet its needs. By requiring explicit consideration of all costs incurred during the life of a project, LCCA is able to identify the lowest total-cost alternative to meet the performance requirements of the project. By quantifying work zone user delay, LCCA includes the effects of work zones on road users. Finally, documentation of the assumptions made and inputs used in the LCCA provides the means to communicate PennDOT's decision rationale to interested stakeholders.

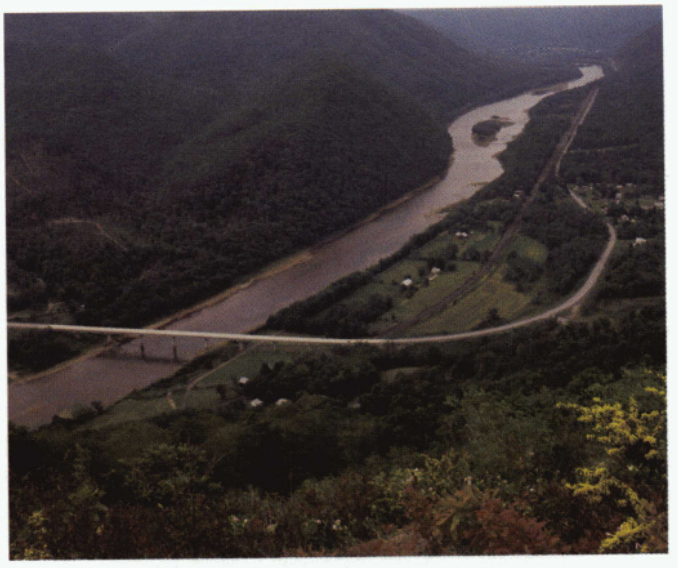
HOW DID PENNDOT GET THERE?

PennDOT's LCCA Program

In the mid 1980s, PennDOT initiated a policy requiring that LCCA be performed for all interstate highway projects with estimated initial costs of more than $1 million and for all other projects with estimated initial costs of more than $10 million. About 15 to 20 pavement projects each year are of sufficient scale to warrant an LCCA under this policy. PennDOT relies on agency life-cycle costs to make its pavement design selection; however, when the agency life-cycle costs of different alternatives are sufficiently close, the life-cycle costs to users are included in the analysis. All PennDOT pavement analyses are performed in accordance with LCCA procedures contained in the Pavement Policy Manual, PennDOT Publication 242, which also explains the pavement design procedure.

Pavement Design Procedure

PennDOT stipulates that its principal routes be designed to produce 20 years of performance using the 1993 AASHTO Design Procedure. The inputs to this procedure—initial average daily traffic, anticipated traffic growth, desired performance period, and paving material characteristics—generally determine the required pavement design for any paving material.



Bridge over the Susquehanna River

Pavement designs, whether for initial road construction, adding capacity, or pavement rehabilitation projects, are performed by engineers at PennDOT's engineering districts. District office engineers design the pavement, investigate right-of-way requirements, and conduct environmental reviews. Additionally, these engineers must produce an LCCA for projects when required by policy. The selected project design and its supporting documentation, including the LCCA, are sent for review to the Pavement Design and Analysis Section of the Bureau of Maintenance and Operations at PennDOT's central office in Harrisburg. Project approval is contingent upon successfully passing the State-level review in all design areas, including determination of the long-term, least-cost alternative for projects where an LCCA is required.

PennDOT's LCCA Method

If an LCCA is required, PennDOT pavement design selection guidelines require engineers to compare at least one bituminous and one Portland cement concrete design alternative for each project. All competing

District office engineers design the pavement, investigate right-of-way requirements, conduct environmental reviews, and, when required by policy, produce an LCCA.

PennDOT uses a 40-year analysis period to capture costs from initial construction and rehabilitation activities.

pavement alternative designs are compared over a 40-year analysis period (which accounts for the 20-year initial design standard and subsequent rehabilitation requirements). Each design alternative being considered must meet the performance requirements of the project throughout the analysis period. Accordingly, for each competing alternative, the design engineer must identify the initial construction activities as well as all future rehabilitation and maintenance activities that are needed to ensure the performance of the pavement. The result is a schedule for each alternative of when future maintenance and rehabilitation activities will occur, when agency funds will be expended, and when and for how long the agency will establish work zones.

The design engineer must then calculate the agency and user costs for these activities. Work zone user costs are calculated from the additional delay and vehicle operating costs due to the effects of work zones on roadway capacity. PennDOT has determined that as all alternatives will,

Schuylkill Expressway, southwest Philadelphia

by design, provide similar performance, the only quantified difference in user costs will be due to work zone effects.

Estimates of agency and user costs in an LCCA are developed in constant (i.e., real) dollars, which do not include an inflation component. For example, the same unit values for material, labor, and user time used to estimate the agency and user costs of an activity occurring in the first year of the analysis period would be used to estimate costs for every anticipated activity in the analysis period.

PennDOT uses a discount rate of 6 percent to convert anticipated future costs to present dollar values so that the total costs of different alternatives can be directly compared.

At this point, the total life-cycle agency and user costs of each alternative are calculated. However, dollars spent at different times have different values to the agency from the standpoint of the present day (e.g., $100 today has a greater present value than $100 made available 20 years from now). Therefore the projected activity costs for an alternative cannot simply be summed to calculate total life-cycle cost for that alternative. PennDOT uses economic methods (e.g., discounting) to convert anticipated future costs to present dollar values so that the total costs of different alternatives can be directly compared. PennDOT uses a real discount rate of 6 percent, which like the agency and user costs, excludes the effects of inflation. This discount rate has been derived from an average, long-term State bond rate with the inflation component removed.

Costs Typically Considered in Life-Cycle Cost Analysis

Agency Costs
Design and engineering
Construction
Reconstruction/Rehabilitation
Preservation/Routine maintenance
Maintenance of traffic
User Costs Associated With Work Zones
Delays
Vehicle operating costs

If the difference between the alternative with the least agency cost and all other alternatives is greater than 10 percent, the least-cost alternative is selected. If the difference is less than 10 percent, another design, which does not have the least cost, may be chosen, and other factors are consulted in the selection. This selection process acknowledges that there is an element of uncertainty in LCCA results. The other factors considered are the user life-cycle costs, constructability considerations, and the performance of similar pavements in the same geographic area.

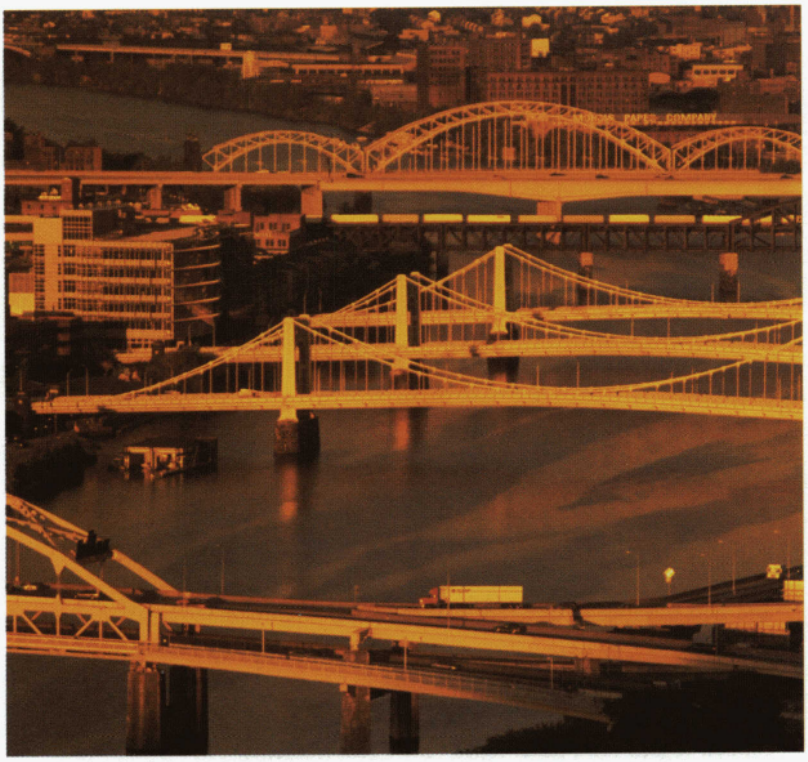
When the pavement design is completed, it is submitted by the district to the Design and Analysis Section at PennDOT's central office. After all aspects of the design are reviewed by this section and the LCCA results are verified, the pavement design is approved.

LCCA Data Requirements

LCCA is data-intensive. It specifically requires cost and performance data for construction and rehabilitation activities. When PennDOT began using LCCA, it did not possess a historical database to support the needs of the program. The first analyses used cost estimates and performance periods developed through expert opinion.

As PennDOT's LCCA process evolved, the agency set out to secure the necessary data. However, it was not necessary to develop a database specifically for LCCA, since two existing information systems were found to have the requisite information and are now used to supply data to the LCCA process. The Contract Management System contains bid history data with the ability to sort that data by project characteristics such as project size, location, and traffic. The Roadway Management System contains current and historic pavement condition inspection data. Combining the information in these two systems allows PennDOT pavement designers to develop cost and performance data inputs for use in an LCCA.

PennDOT standardized all pavement design processes, including LCCA, in two manuals: Highway Geometric Design Manual and Pavement Policy Manual.



Allegheny bridges, Pittsburgh

LCCA Implementation

PennDOT took a decidedly top-down approach to its LCCA implementation. The department reviewed its entire pavement design and selection process. Then the PennDOT director created a special task force to review new technologies for their applicability to Pennsylvania's transportation system. LCCA was chosen as a methodology that met PennDOT's requirements for determining long-term agency and user costs.

Working with internal experts, the Pennsylvania State University, and industry groups, PennDOT developed its Highway Geometric Design Manual and its Pavement Policy Manual. These manuals standardized all pavement design processes, including LCCA. By the mid 1980s, these manuals were being used by every PennDOT pavement designer.

WAS IT WORTH IT?

Benefits of LCCA Implementation

PennDOT credits its LCCA program with benefits to the department in several areas:

Pavement Design. PennDOT has found that pavements designed since the implementation of its LCCA program perform better than pavements designed before implementation. The data requirements of the LCCA process have improved the quality of all pavement design inputs and have led to better pavement designs.

Professional Development. By requiring cost and performance inputs for initial and rehabilitation construction activities as well as for multiple types of materials, LCCA provides pavement design engineers with the opportunity to investigate aspects beyond initial construction design. PennDOT engineers have become more knowledgeable about the costs and performance of different pavement materials and activities, and they are better able to design and estimate to a project's requirements. Additionally, designers are better informed about pavement rehabilitation and preventive maintenance practices than engineers who design without explicit regard for a pavement's future requirements.

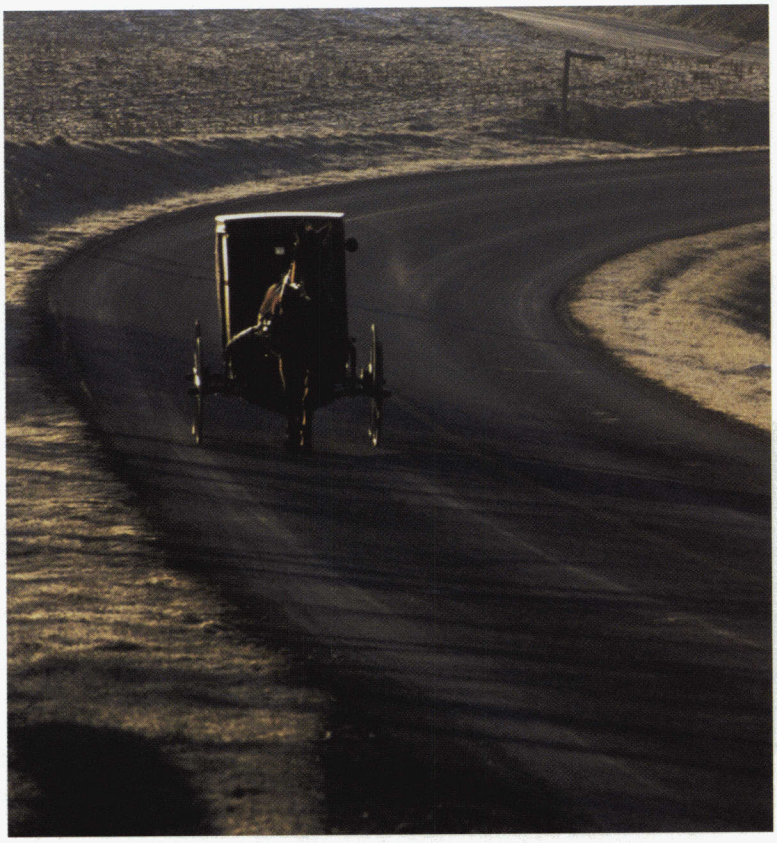
Competition. By standardizing its pavement design selection process with LCCA, PennDOT established clear benchmarks for pavement performance. The asphalt and concrete industries have met the challenge imposed by PennDOT and have adapted with better and lower cost products. Additionally, contractors have lowered their bid prices in order to remain competitive in a standardized environment.

PennDOT engineers have become more knowledgeable about the costs and performance of various pavement materials and activities. The LCCA process provides opportunities to investigate aspects of pavement life beyond initial construction design.

Credibility. PennDOT's well-documented, centrally regulated LCCA process improves the transparency of the pavement-type selection process and makes pavement selection decisions less likely to be contested by pavement industry groups.

User Costs. With the capacity on many roadways already taxed, PennDOT has formally recognized that work zone activities cause roadway users delay and additional vehicle operating costs. PennDOT uses LCCA as a framework for considering tradeoffs between user costs and agency expenses at the project level.

Horse and buggy on paved road, Churchtown



WHAT HAS PENNDOT LEARNED?

Although LCCA has provided real benefits to PennDOT, implementation was not without challenges.

LCCA Data Inputs. PennDOT has relied on both expert opinion and historical data to develop LCCA inputs. PennDOT recognized its lack of systematic data as a potential implementation roadblock, and specifically decided to use documented expert opinion before it had a source of properly analyzed historical data. At the same time, existing databases were investigated for their ability to supply these inputs. By developing the process at the same time as data sources, PennDOT was able to implement its LCCA program much earlier than it would have if the process and inputs had been developed sequentially.

User Costs. PennDOT recognizes that including work zone user costs in its pavement selection process is an extension of its interest in normal operations levels of service. As consideration of user costs is an integral part of the department's statewide planning process, PennDOT decided that user costs should be applied to the project-level decision process as well. The methodology that PennDOT uses to quantify work zone user costs, including user time values, is derived from National Cooperative Highway Research Program Report 133, "Procedures for Estimating Highway User Costs, Air Pollution, and Noise Effects."

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Uncertainty. Recognizing that LCCA inputs are uncertain, PennDOT has modified its pavement selection criteria accordingly. PennDOT makes pavement design decisions based upon the information supplied by its LCCA process. However, LCCA inputs, such as agency costs and pavement performance, cannot be predicted with com-

plete certainty. Consequently, when the total agency costs of different alternatives are similar, other factors are specifically included in the decision process. PennDOT believes that the "10 percent rule" accounts for uncertainty in LCCA inputs and allows engineering judgment to be incorporated into the pavement design selection decision.

Industry Relationships. PennDOT has reached out to the State's paving industry groups in order to improve their understanding of PennDOT's selection process. Making the pavement-type selection process transparent has enhanced the credibility of the process and has turned potential adversaries into allies.

WHAT'S NEXT?

PennDOT practices continuous process improvement with its pavement selection decision process. While the existing pavement selection method has achieved what was only hoped for 20 years ago, the department has decided to contract for a review of its processes. This review will be independent of the department and conducted by pavement experts not employed by PennDOT. Specifically, the review will examine the role of user costs and the accommodation of uncertainty in the analysis. Although PennDOT does not anticipate any major changes in its selection method, the benefits that the LCCA program brings—improved credibility, improved designs, and lower costs—are such that PennDOT wishes to ensure their continuity.

Benjamin Franklin Bridge, Philadelphia

Federal Highway Administration LCCA Products

Available from the Federal Highway Administration are an LCCA Technical Bulletin, the LCCA Primer, and probabilistic pavement LCCA software and its accompanying day-and-a-half workshop. The Technical Bulletin, "Life-Cycle Cost Analysis in Pavement Design," documents best-practice LCCA methods and discusses issues surrounding LCCA. The LCCA Primer is an executive-level treatment of the subject. The software and workshop have been designed to follow best-practice LCCA methods. They allow agencies to investigate the full range of effects on pavement design selection caused by discount rates, user costs, and data uncertainty.

For assistance in implementing an LCCA program or to learn more about these products, please contact the Office of Asset Management at 202-366-0392.

For more information about LCCA, visit the Federal Highway Administration's LCCA Web site:
http://www.fhwa.dot.gov/infrastructure/asstmgmt/lcca.htm

Further Information

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